Standards-Based Interoperability for Design to Manufacturing and Quality in the Supply Chain – Part 2

Asa Trainer
GPDIS2017
Phoenix, AZ
Sep 2017

Introduction

- **International TechneGroup Incorporated (ITI)**
  - **Private company headquartered in Cincinnati since 1983**
  - **Development offices in the United States, England, Israel and India**
  - **Engineering software and services**
    - **PLM system migration solutions**
    - **CAD interoperability solutions**

International TechneGroup

- **Asa Trainer**
  - **New England upbringing, military veteran**
  - **Engineering education (UMD, WSU, RPI) and university educator/researcher**
  - **Both aerospace and CAD industry experience**
  - **Interoperability solutions development**
  - **US and foreign patents in interoperability**
  - **International consortia team member**
  - **Interoperability product / process / program management**

Acknowledgements

- **The work described here is funded by**
  - **NIST Grant (CA) 70NANB14H314**
    - **Investigating the Impact of Standards-Based Interoperability for Design to Manufacturing and Quality in the Supply Chain**
  - **NIST Grant (CA) 70NANB14H256**
    - **Validation for Downstream Computer Aided Manufacturing and Coordinate Metrology Processes**
  - **DMDII-14-06-05**
    - **Digital Standards for the Advanced Manufacturing Enterprise "Operate, Orchestrate and Originate (O3)"**

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

DMDII
DIGITAL MANUFACTURING AND DESIGN INNOVATION INSTITUTE

Building Blocks to a Stds-based MBE Process

NIST Sponsored

D2MIV 2
- Can we close upstream info gaps needed for downstream processes?
- Can we move downstream MBD back upstream as feedback via a Std?

D2MIV 1
- Can we validate downstream MBD data against its upstream source?
- Can we map the upstream MBD Std to the downstream MBD Std?

D2MI
- Can we move MBD data to downstream processes (CAM/CAI) via a Std?
- Is there a demonstrable ROI in taking the MBD downstream?

Conf/Val 2
- Can we extend the Test Cases to include more “real-world” elements?
- If we do, what impact will it have on the results?

Conf/Val 1
- Can we define meaningful MBD Test Cases and Model them in CAD?
- Can we Verify that the models accurately represent the test cases?
- Can we create MBD Std-based Derivatives and Validate them?

SFA
- Can we Validate STEP files for proper STEP syntax?
- Can we coax better STEP file translators out of CAD OEMs & vendors?

Building Blocks to a Stds-based MBE Process

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Commercially-sponsored
& other non-NIST research

DMDII O3	Can we provide near real-time design change to the downstream users? Can we provide rapid feedback to designers & planners during simulation or execution?
OSD TDGV Proto	Is there a better way to control geometric quality than global tolerances? Can tolerance data in PMI be used to control variation in nominal geometry?
CAx-IF 3DPDF-IF	Can the NIST benchmark data and verification/validation processes be used to drive improvement in commercial MBD (interoperability) processes?
JT-IF	Can the NIST benchmark data be used to drive improvement In commercial MBD (interoperability) processes?
End-user Companies	Can end-user companies leverage the NIST benchmark data and verification/validation processes?
CAx & Interop. Vendors	Can CAx and Interoperability vendors leverage the NIST benchmark data and verification/validation processes?

Design to Manufacturing

D2MI

The Team

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Rockwell Collins

GMM
Geater Machining & Manufacturing, Co.

ITI
International TechneGroup

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

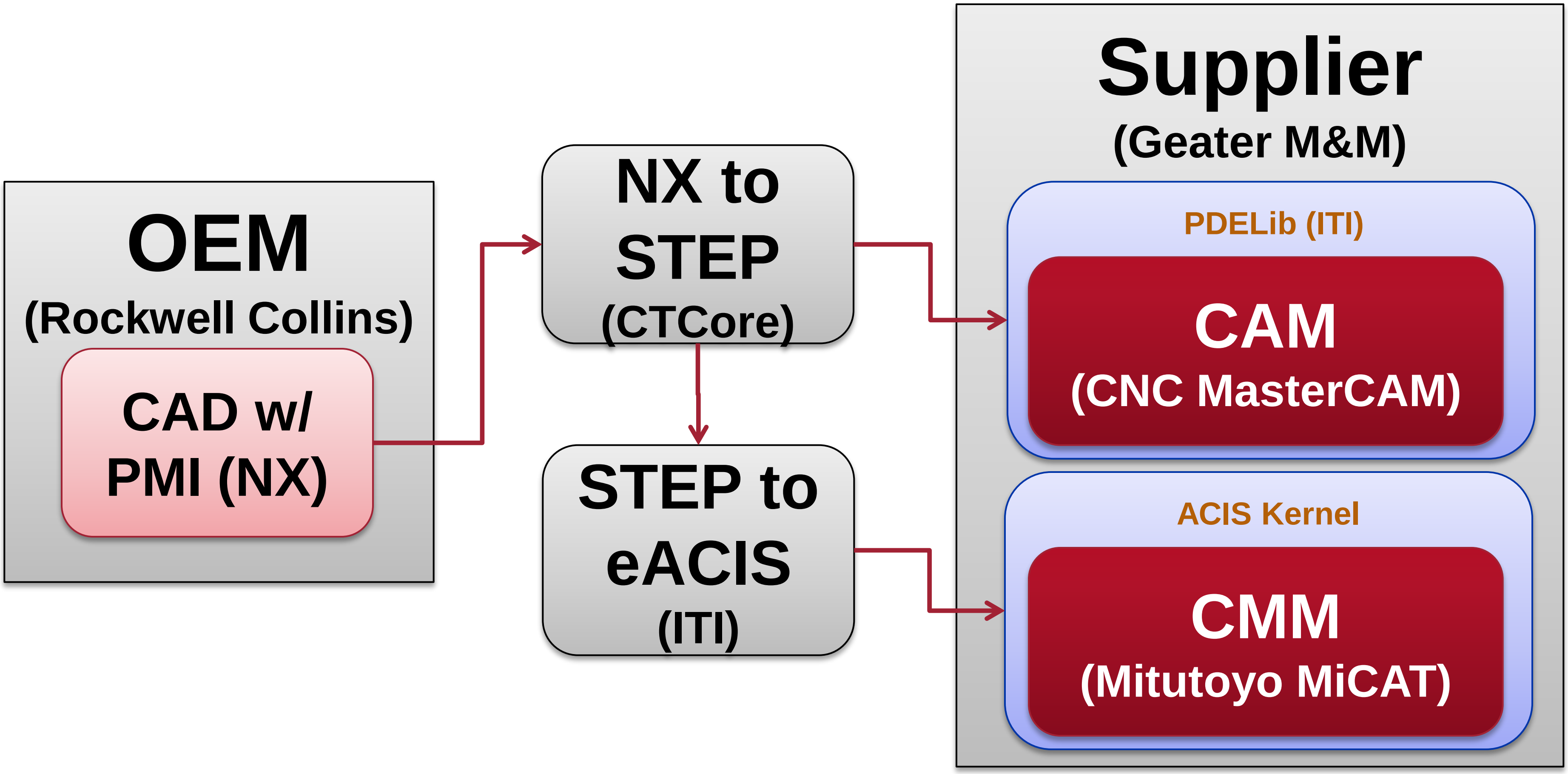
Mitutoyo

Mastercam®

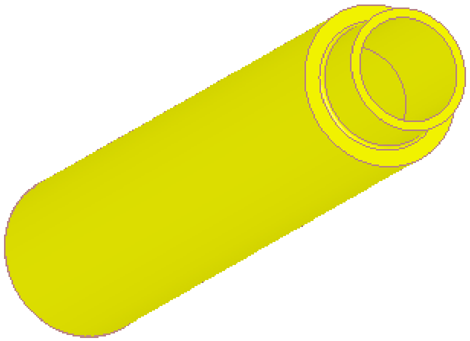
CORETECHNOLOGIE

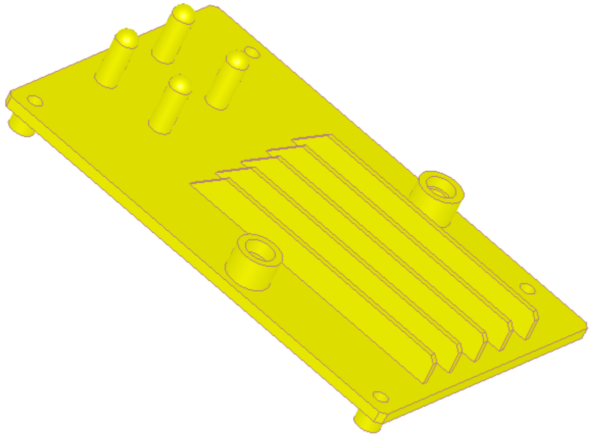
ACCR
ADVANCED COLLABORATION CONSULTING RESOURCES

Data Exchange from CAD-to-CAM and CAD-to-CMM



Test Models and Results Metrics





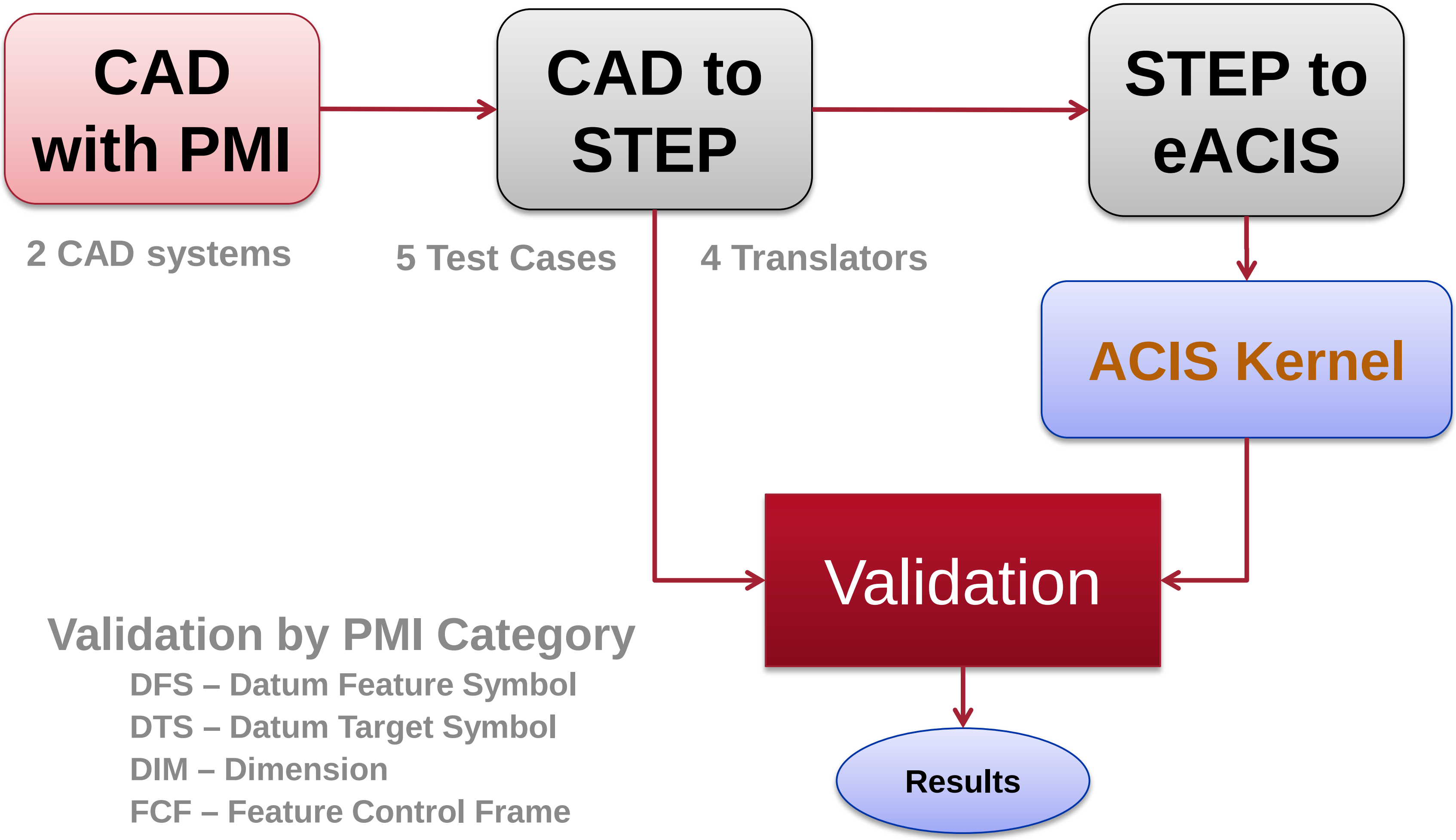
- **CAD Model Creation Metrics**
  - **Introducing MBD Process into Design Org had some ramp-up (CAD system MBD issues, training reqmnts, etc)**
- **CAM Model Creation Metrics**
  - **MBD approach had similar cost to 2D approach**
- **CMM Model Creation Metrics**
  - ***70% reduction in cost*** **over traditional 2D exchange**

Please refer to Part 1 presentation, GPDIS 2016, for additional details

Design to Metrology Validation

D2MIV 1

Data Exchange from CAD-to-CMM (STEP to eACIS) with Validation



Validation by PMI Category

- DFS – Datum Feature Symbol
- DTS – Datum Target Symbol
- DIM – Dimension
- FCF – Feature Control Frame
- Notes – Free Standing Notes

D2MIV Results Summary

- **RC Models**
  - **Focused on Heat Sink model – validation 99% clean**
  - **Issues with Dims on Stand-off Model**
- **NIST CTCs**
  - **25 models from 2 CAD systems, 5 vendors**
  - **Datum Targets were biggest issue (all systems, all vendors)**
  - **Success Rate – Avg - 80% (StdDev 15%)**
    - **One model bad (all systems, all vendors)**

Please refer to Part 1 presentation, GPDIS 2016, for additional details

Validation of extended-ACIS PMI representation with Source STEP Model

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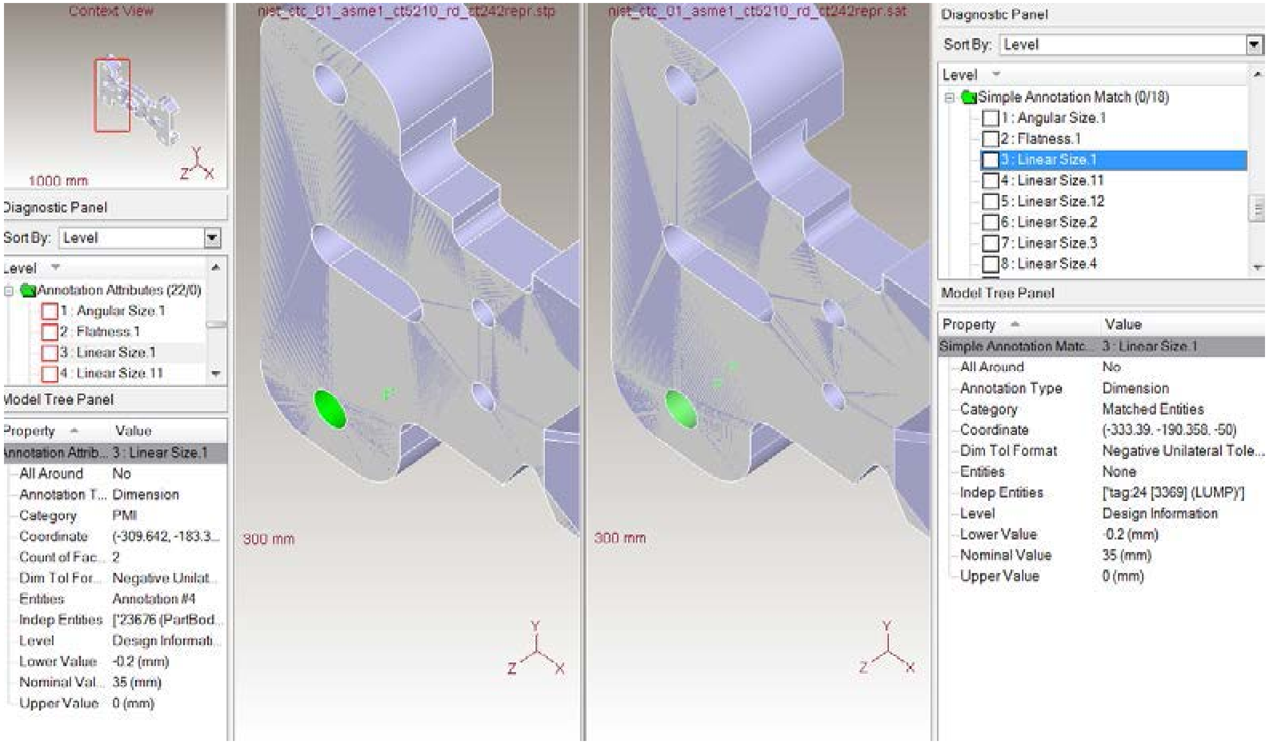
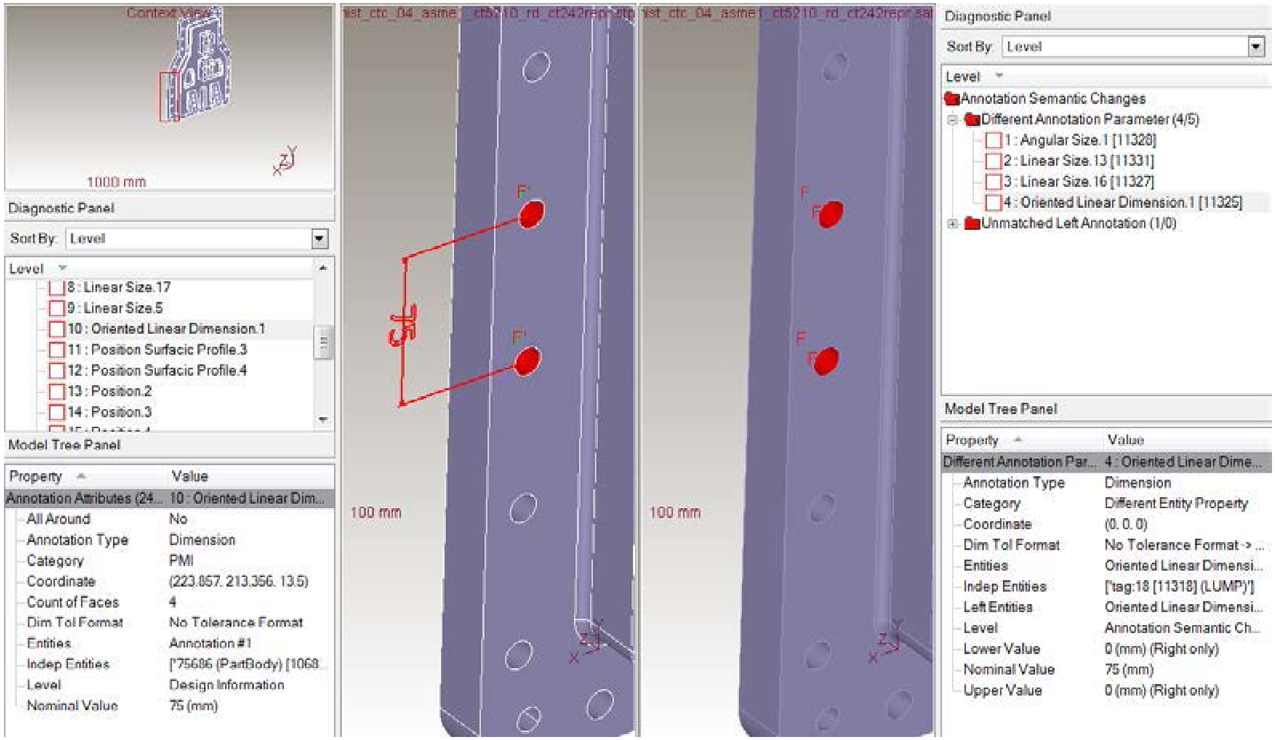


Validation of extended-ACIS PMI representation with source STEP Model illustrating an anomaly



Validation illustrating loss of Associated Geometry for a Datum Target Symbol in target ACIS model

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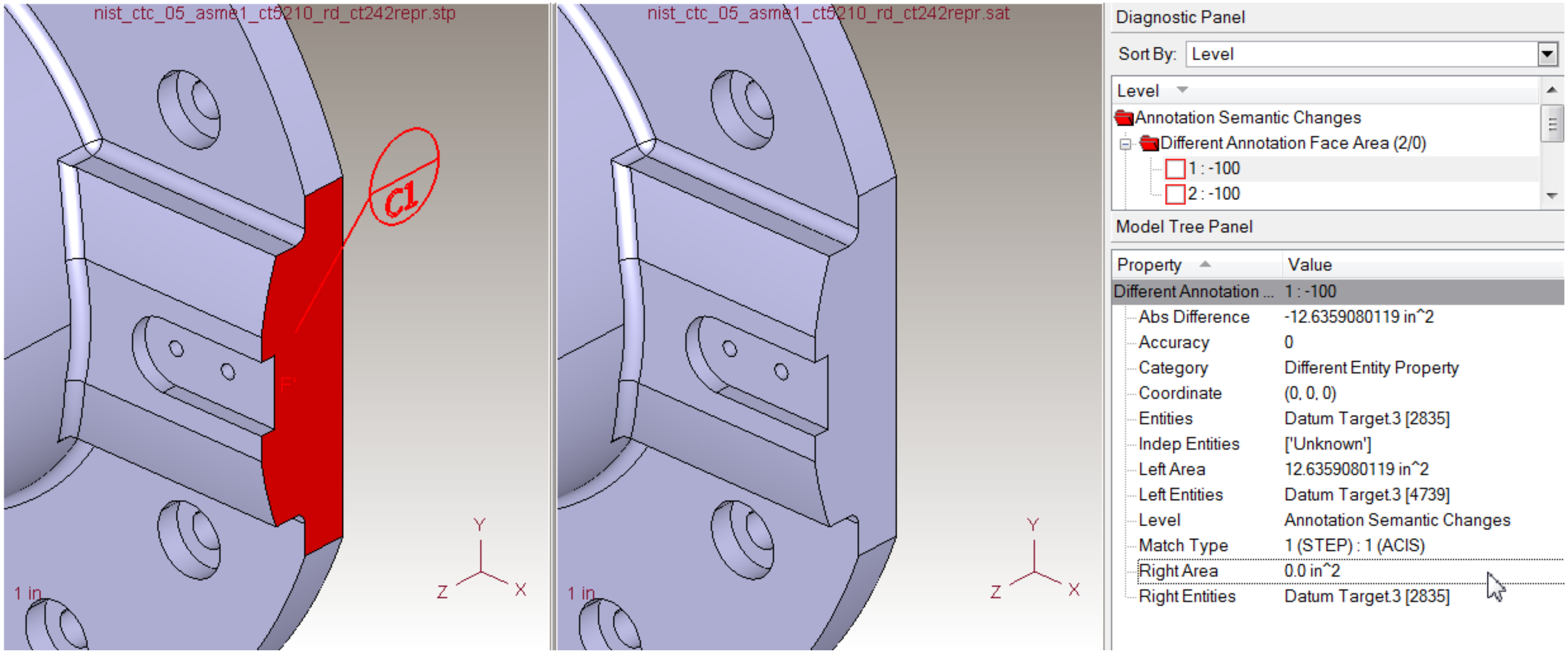

Change to Feature Control Frame primary datum reference frame identifier

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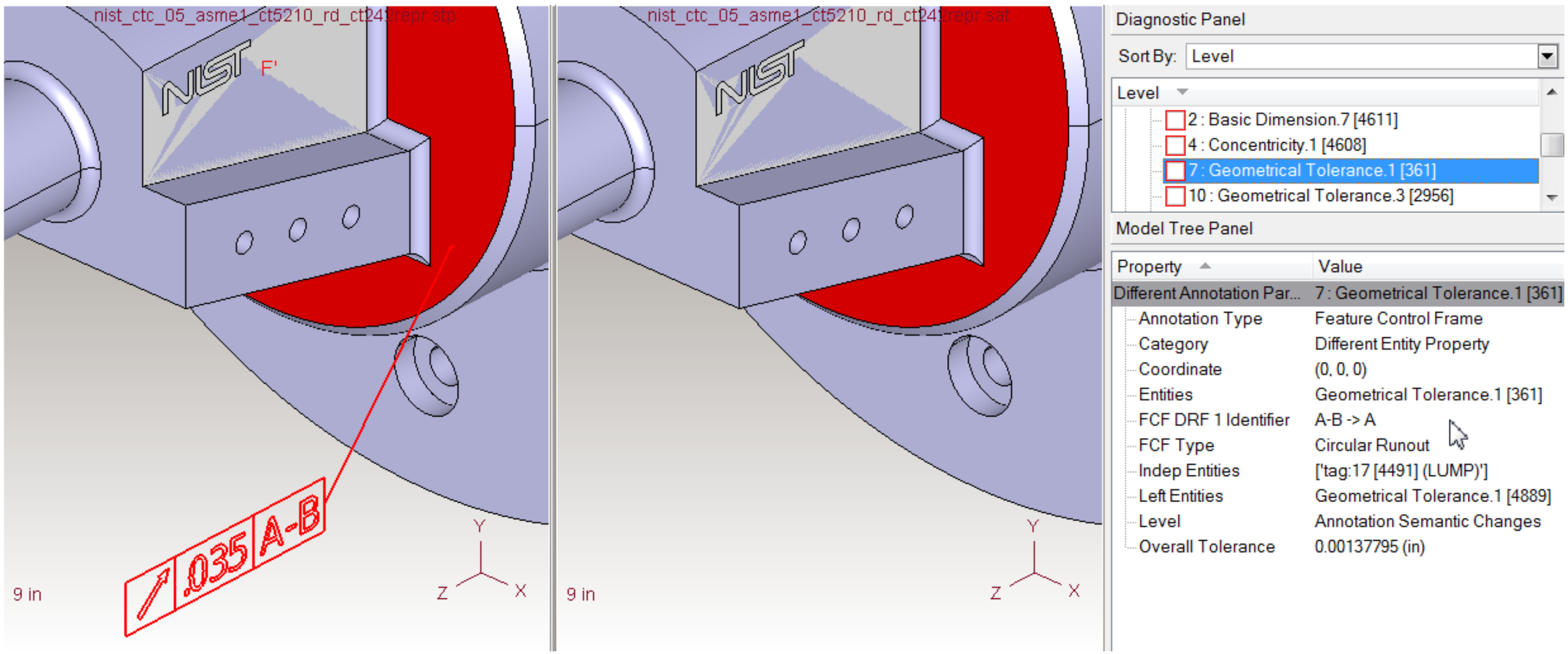

STEP-QIF Mapping Tables - Classes

- **PMI**
  - **Dimension Types (19/21)**
  - **Dimension Tolerance Principle (2/2)**
  - **Dimension values (45/48)**
  - **Tolerance Types (15/18)**
  - **Tolerance Zone (13/18)**
  - **Tolerance Modifiers (17/21)**
  - **Unit based Tolerance (9/9)**
  - **Datum reference modifiers (25/32)**
- **Shape**
  - **Topology (8/8)**
  - **Surface Geometry (11/11)**
  - **Curve Geometry (10/10)**

(# of STEP elements / # of QIF elements)

- **Links**
  - **PMI <-> Brep (both)**
  - **PMI <-> Polyline presentation (both)**
- **Miscellaneous**
  - **Notes (both)**
  - **Flag Notes (QIF)**
  - **Surface Finish (QIF)**
  - **Tables (none)**
  - **Global or General Tolerances (none)**
  - **Views (both)**

Please refer to Part 1 presentation, GPDIS 2016, for additional details

Results

- **Successfully demonstrated transfer of MBD design models from OEM to Supplier and from CAD to CAM and CM systems**
- **Proved that, for metrology, savings for MBD transfer over traditional, non-MBD, was significant (70% reduction in overall process time)**
- **Validation was a valuable check on data quality**
- **STEP and QIF have similar coverage, ACIS had gaps**

Design to Metrology
Filling in the Gaps

D2MIV 2

DMDII O3

MBE Processes

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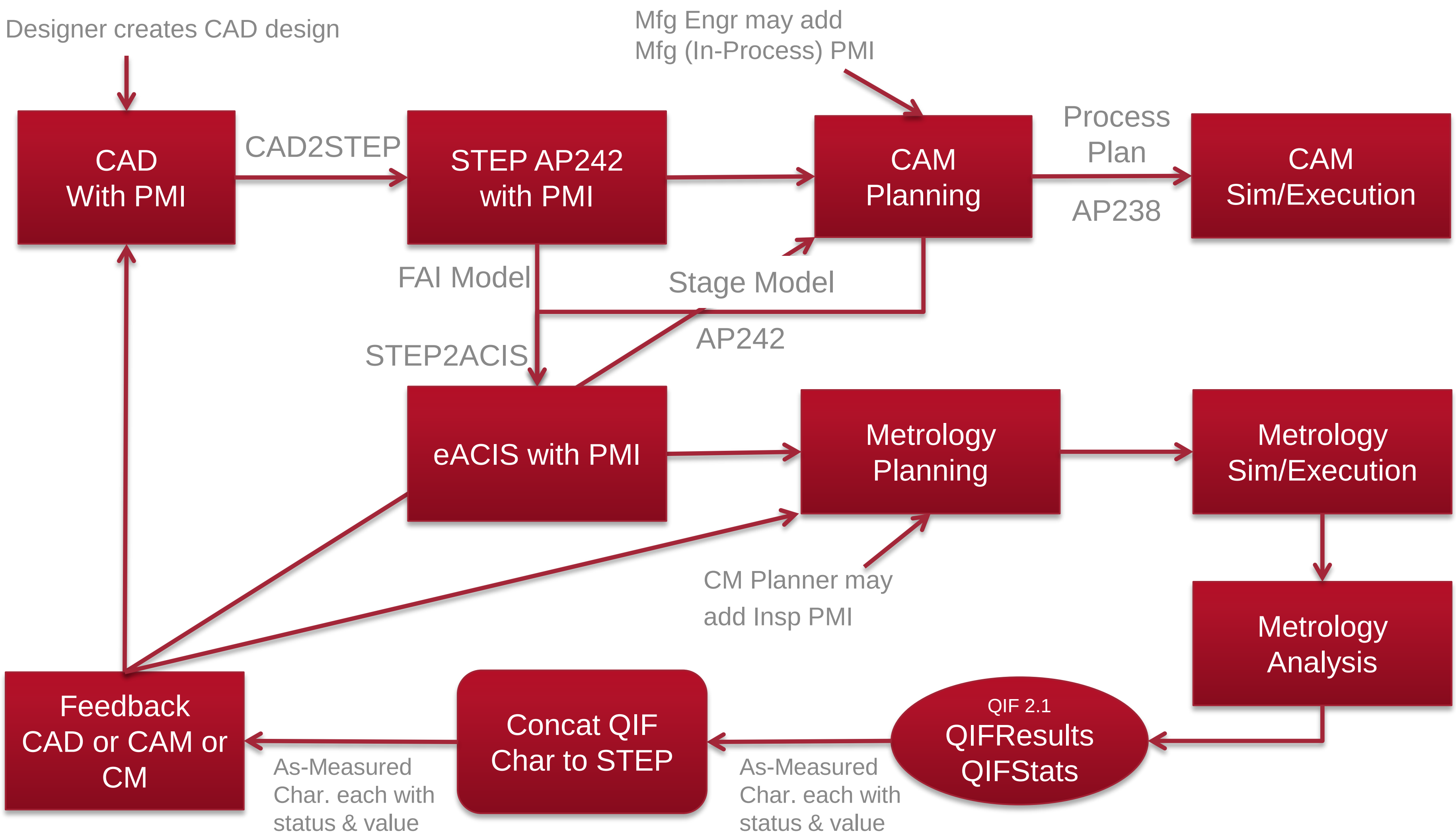

Last Year's Next Steps

- **Gaps in PMI support important for Mfg/Metrology**
  - **Surface Finish, Welds, Material**
  - **Inclusion of Precision**
  - **UOS Tolerance**
- **Management of UUIDs for Traceability**
  - **Choice of UUID class**
  - **Insertion/Extraction of UUIDs on PMI**
- **Demonstration of feedback from Metrology (QIF) to Design/Manufacturing (STEP)**
  - **Alternate Shape Representations**
  - **Alternate PMI elements**
  - **Status**

The Team

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STEP Tools, Inc.

powered by VIMANA System Insights

DMDII a UI LABS Collaboration

ITI International TechneGroup

Mitutoyo AMERICA CORPORATION

Demonstration Architecture

- **More accurate, more timely and more automated <u>on-machine</u> measurement**

Model 1: Stage model
Model 2: Tooling model
Model 3: Result model

1. AP242 Tolerances

CNC with Twin Models

2. MTConnect Measurements

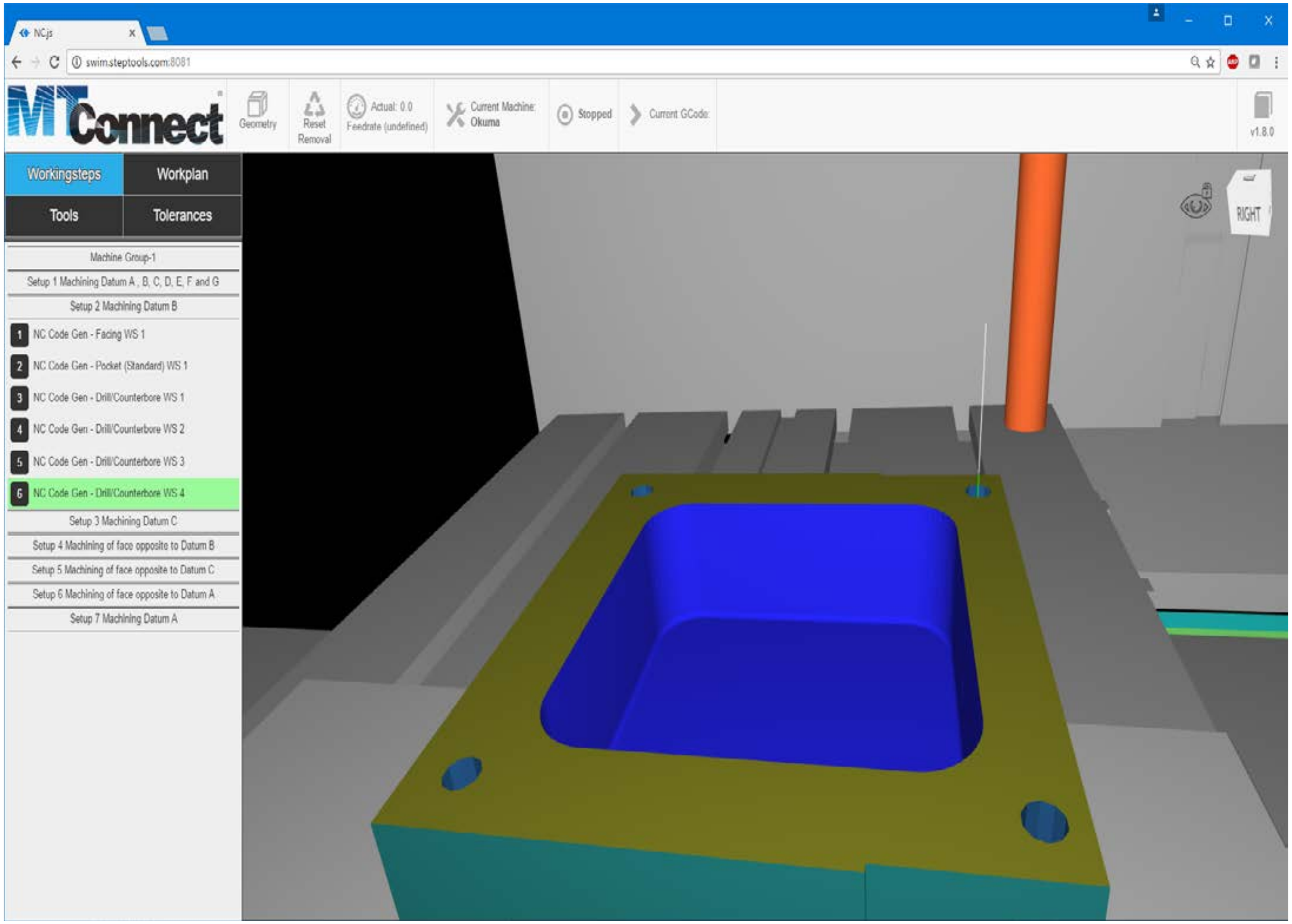
CMM with Gateways

Gate 1: AP242 -> ACIS
Gate 2: MTConnect -> CMM
Gate 3: QIF -> AP242

3. QIF Inspection results

1. Share stage model with required tolerances between CNC and CMM
2. Machine part with results to CMM as touch points on features/characteristics
3. Evaluation of tolerance compliance with results back to CNC for any necessary action

Virtual model of part machined in Mukilteo



Are the features in tolerance?

Measurement Process

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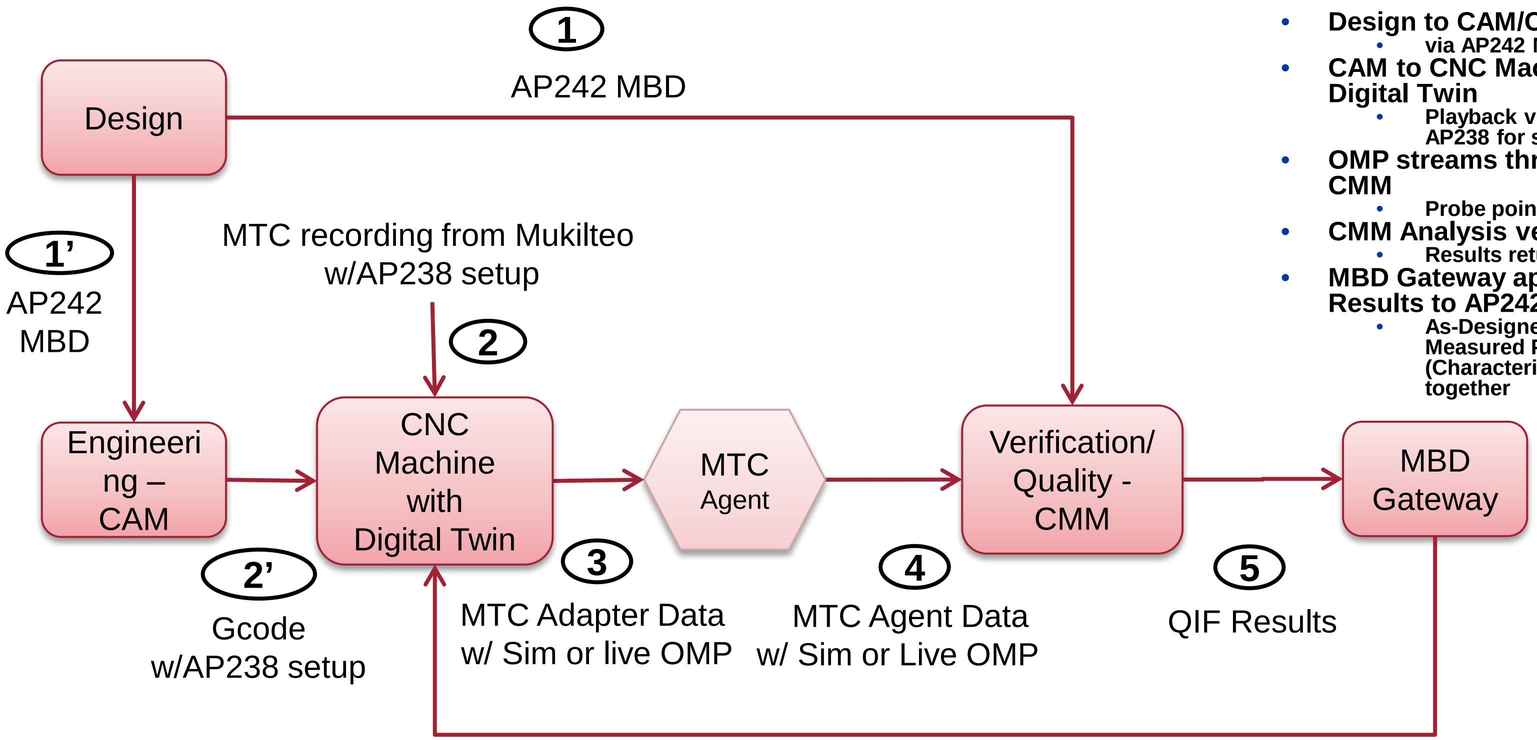

- **Design to CAM/CMM**
  - **via AP242 MBD**
- **CAM to CNC Machine with Digital Twin**
  - **Playback via MTConnect and AP238 for setup**
- **OMP streams through MTC to CMM**
  - **Probe points in part space**
- **CMM Analysis verifies Quality**
  - **Results return QIF Results**
- **MBD Gateway appends QIF Results to AP242**
  - **As-Designed and As-Measured PMI (Characteristics) packaged together**

1' 2' Performed at Mukilteo (see https://www.youtube.com/watch?v=Mjzg5nku5Lg)

1 2 3 4 5 Performed at DMDII with a virtual CNC in NY and a virtual CMM in Chicago

Input: Tolerances and probe points in AP242

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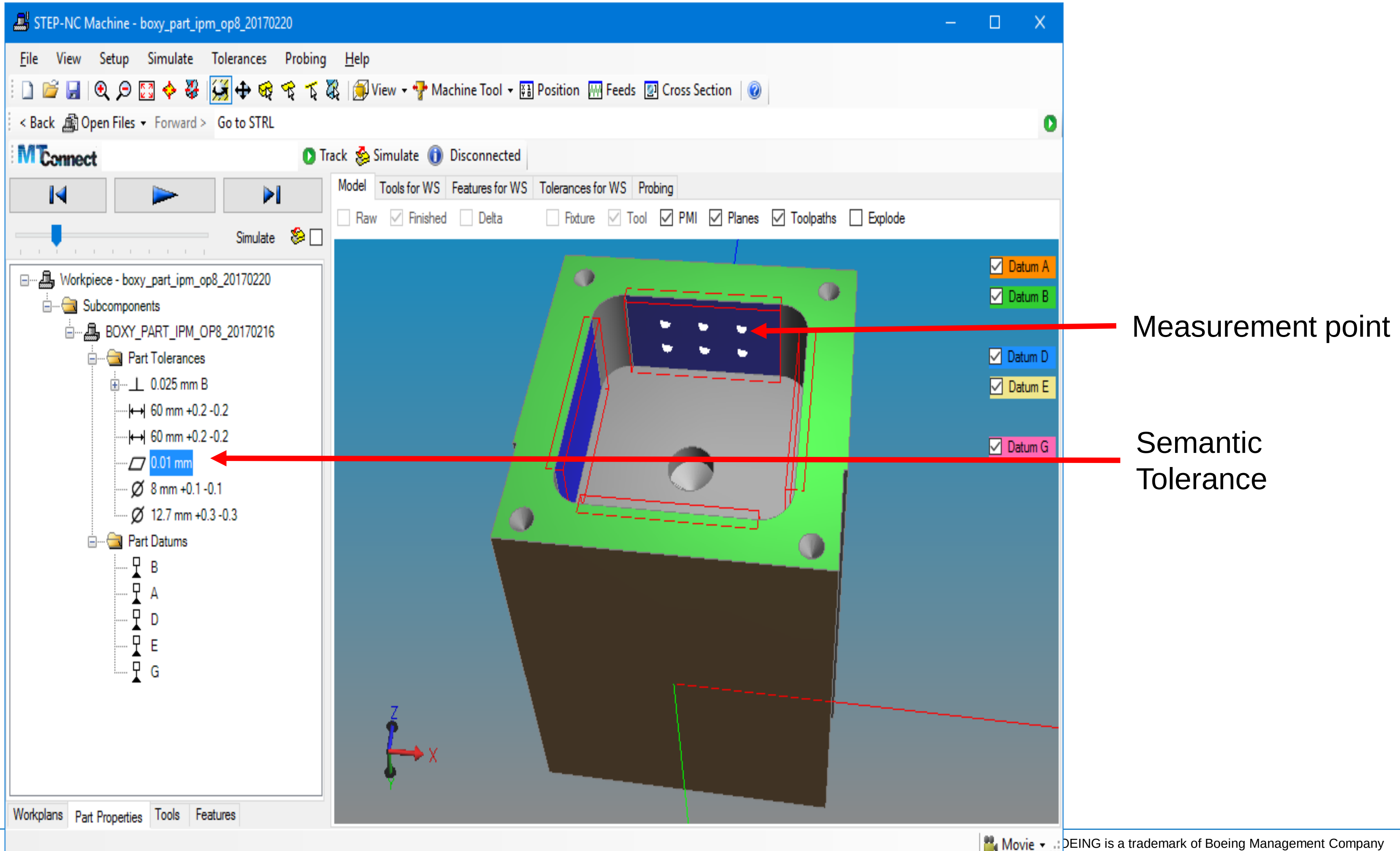
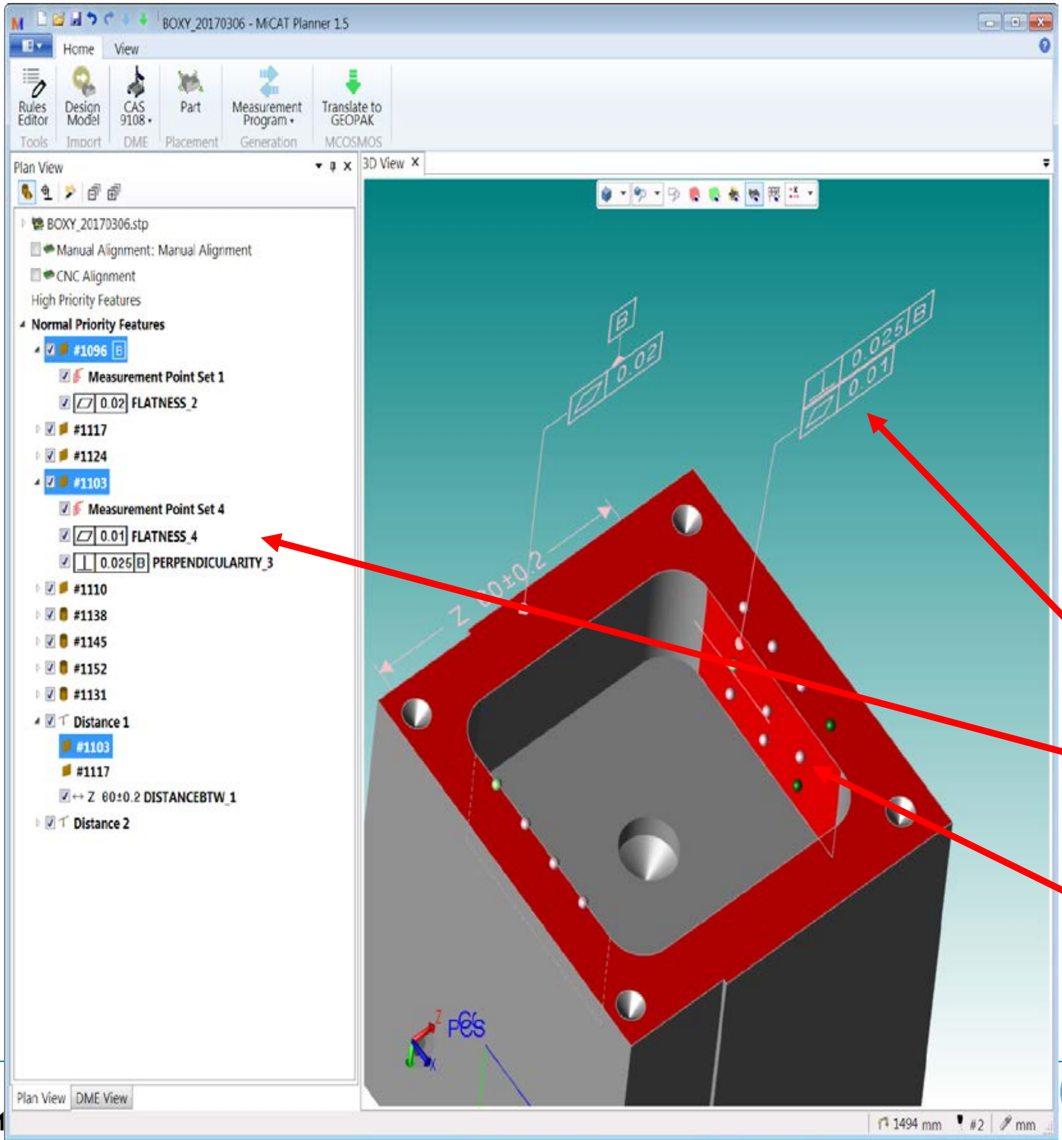


1. Planner*: Measurements from AP242



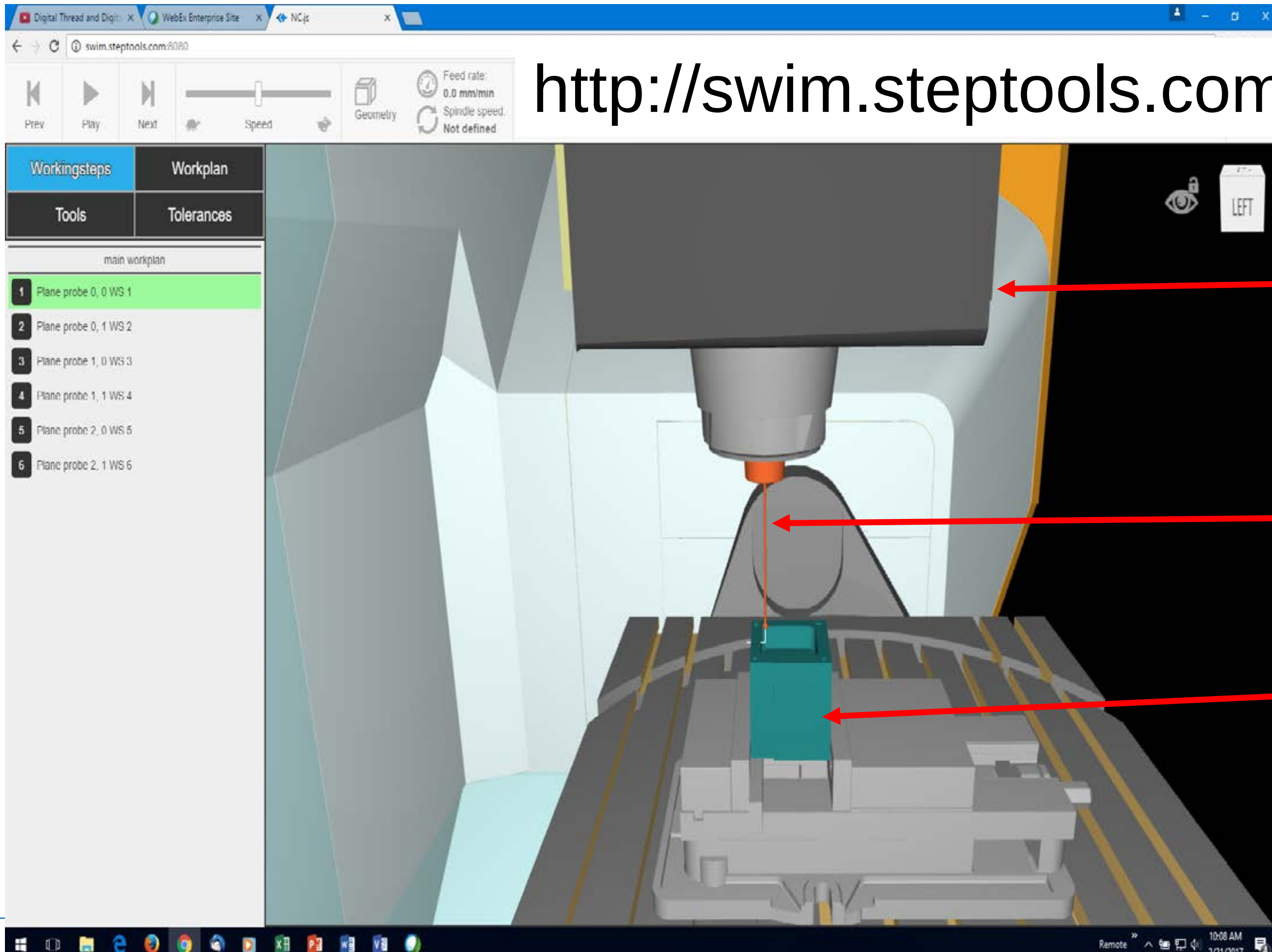
* MiCAT Planner 1.5 special version for DMDII O3 Investigation Only

Semantic Tolerance

Measurement point

2. Digital twin measurements using AP238

http://swim.steptools.com:8080



Machining Twin

Touch Probe

Virtual Part from MTConnect recording

3. Measurement points in MTConnect agent

swim.steptools.com:5000/current

Timestamp	Type	Sub Type	Name	Id	Sequence	Value
2017-02-20T18:41:49.443571Z	Unavailable		system	Msystem	49	

Path : path

Samples

Timestamp	Type	Sub Type	Name	Id	Sequence	Value
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2017-02-20T18:41:49.443571Z	PathFeedrate	ACTUAL	p1Fact	Mp1Fact	28	UNAVAILABLE
2017-02-20T18:41:49.443571Z	PathFeedrate	PROGRAMMED	p1Fcmd	Mp1Fcmd	29	UNAVAILABLE
2017-02-20T18:41:49.443571Z	PathPosition		p1LPathPos	Mp1LPathPos	30	UNAVAILABLE
2017-02-20T18:41:49.443571Z	AccumulatedTime	x:OPERATING_TIME	p1OperatingTime	Mp1OperatingTime	34	UNAVAILABLE
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2017-02-20T18:41:49.443571Z	AccumulatedTime	x:TOTAL_SPINDLE_RUN_TIME	p1TotalSpindleRunTime	Mp1TotalSpindleRunTime	41	UNAVAILABLE

http://swim.steptools.com:5000/current

Events

Timestamp	Type	Sub Type	Name	Id	Sequence	Value
2017-02-20T18:41:49.443571Z	e:BlockNumber		p1BlockNumber	Mp1BlockNumber	24	UNAVAILABLE
2017-02-20T18:41:49.443571Z	e:Variables	x:COMMON	p1CommonVariable	Mp1CommonVariable	25	UNAVAILABLE
2017-02-20T18:41:49.443571Z	ToolNumber		p1CurrentTool	Mp1CurrentTool	26	UNAVAILABLE
2017-02-20T18:41:49.443571Z	e:Macman	x:PANEL_HISTORY	p1MacManPanelHistory	Mp1MacManPanelHistory	31	UNAVAILABLE
2017-02-20T18:41:49.443571Z	e:OutputSignal	x:DRY_RUN	p1MachineOperationPanelOutputDryRun	Mp1MachineOperationPanelOutputDryRun	32	UNAVAILABLE
2017-02-20T18:41:49.443571Z	e:OutputSignal	x:MACHINE_LOCK	p1MachineOperationPanelOutputMachineLock	Mp1MachineOperationPanelOutputMachineLock	33	UNAVAILABLE
2017-02-20T18:41:49.443571Z	ToolAssetId		p1ToolAssetId	Mp1ToolAssetId	37	UNAVAILABLE
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2017-02-21T18:54:35.271Z	Program		pprogram	Mpprogram	346	BOXY_PART_IPM_OP8_20170216
2017-02-21T14:00:32.526-05:00	Measurement		measure	p1_85	365	feature:"9ffd7cbf-25bd-4be9-ab37-90b7ee855c69" order:1 count:6 id:"FACE27463" characteristic:"3DLocation" x:-11.000000 y:-33.333333 z:10.002639

Linear : X

Samples

4. MeasurLink* generating QIF Results

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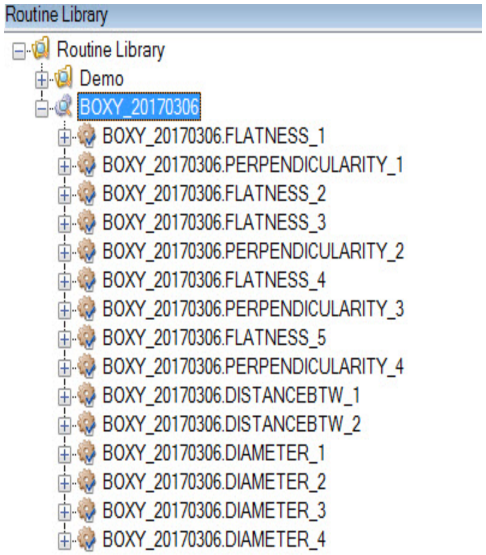

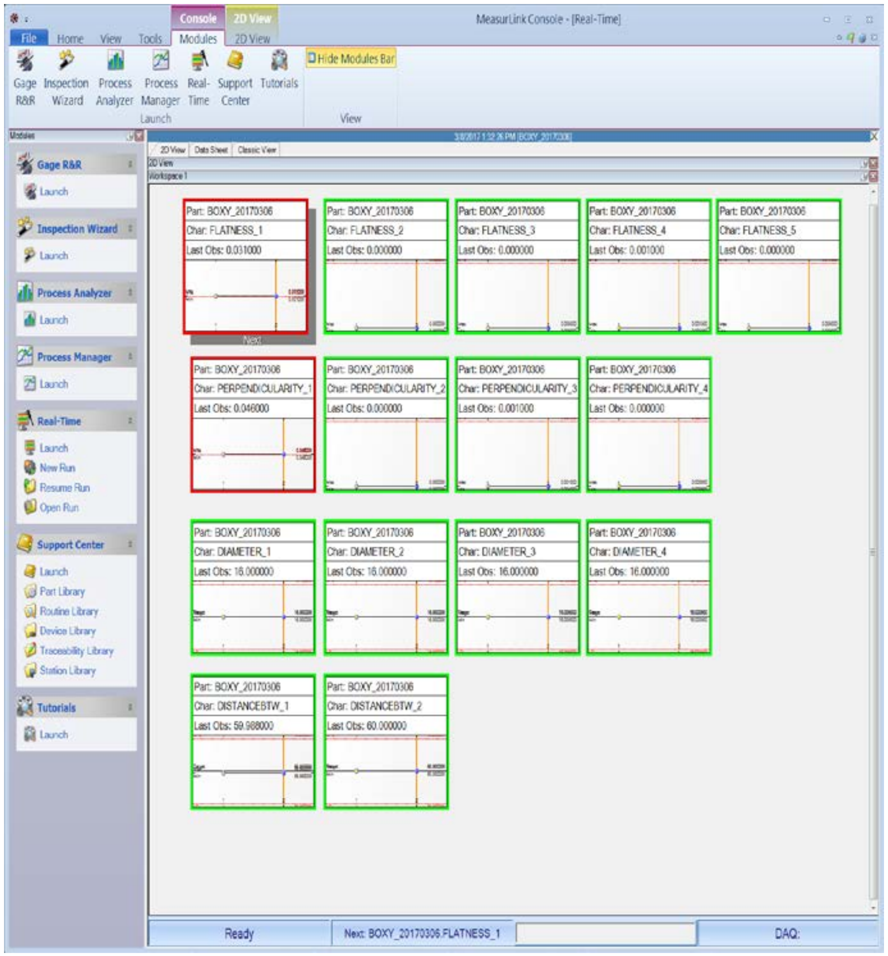

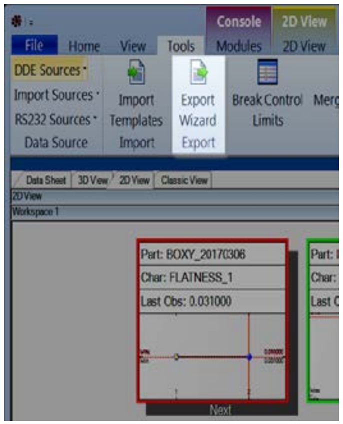

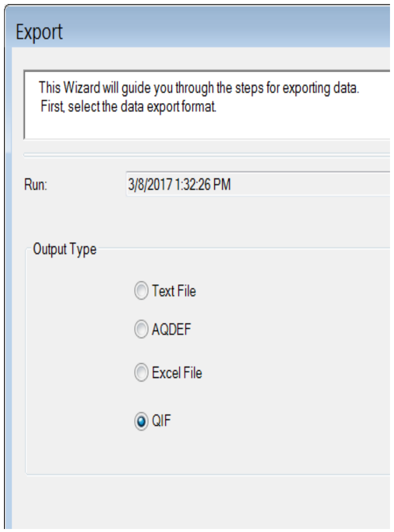

* MeasurLink v8.2.1 (released Dec 2016) and newer

5. Viewer showing QIF Results in AP242

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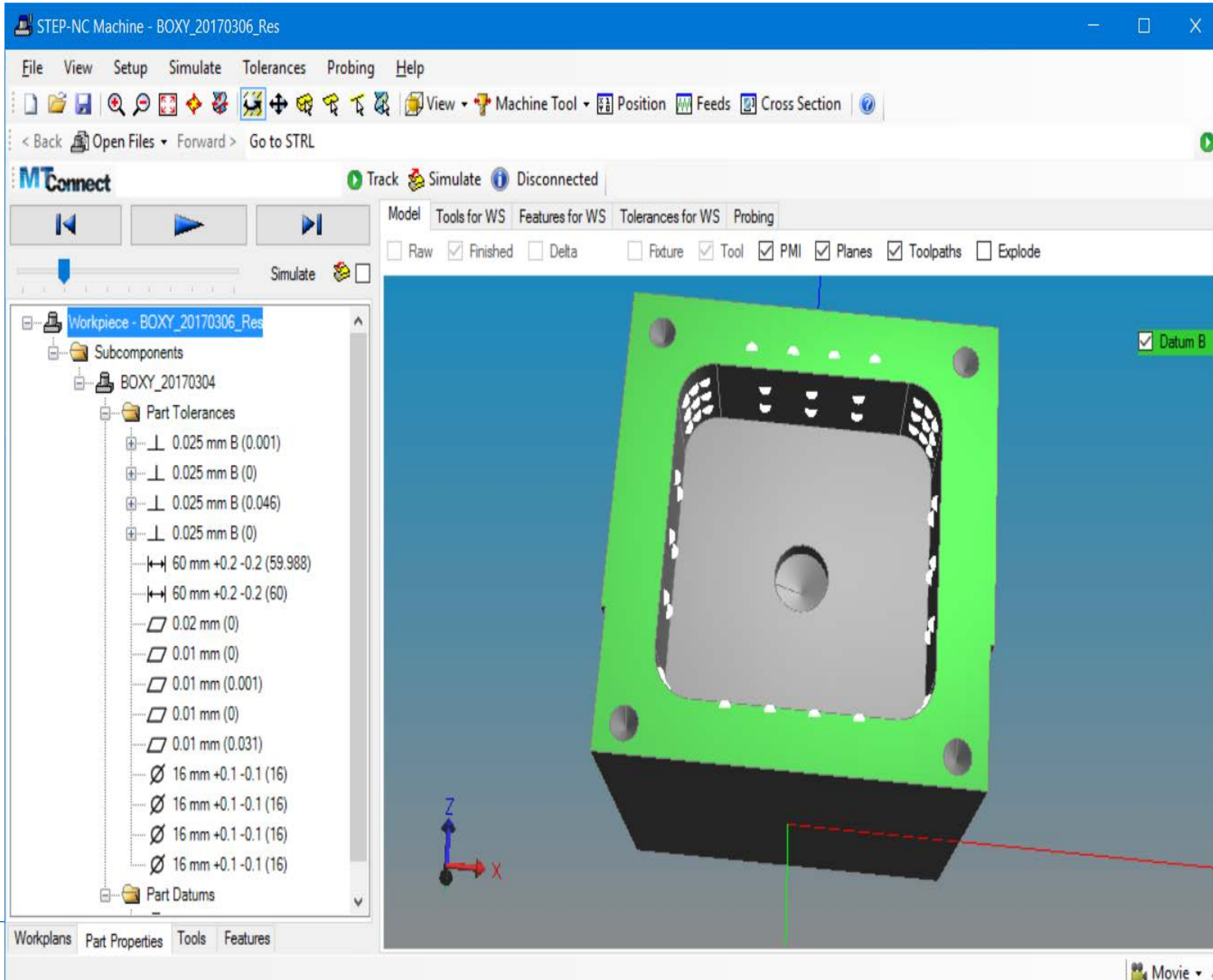

Internal: UUID's that relate all the data

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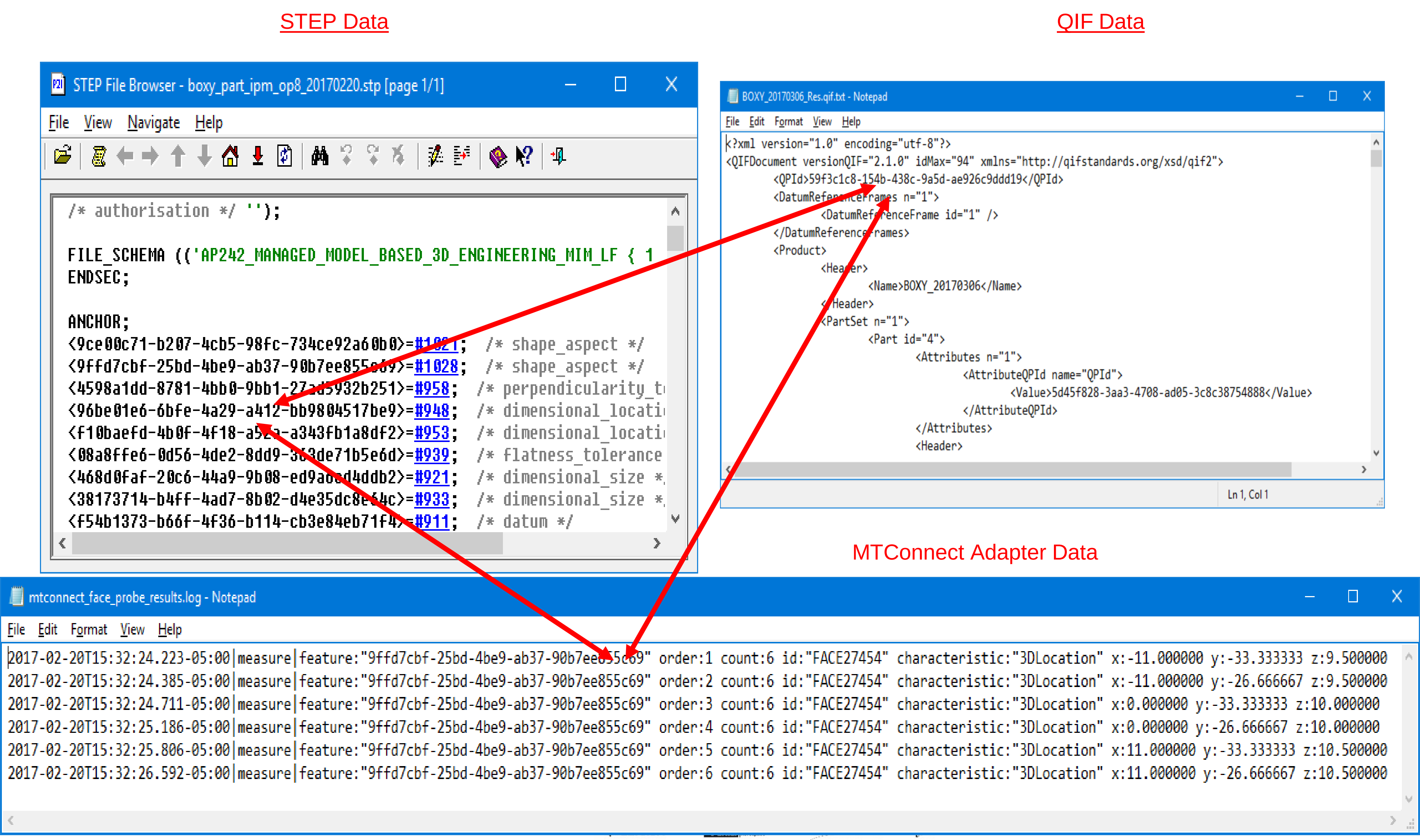
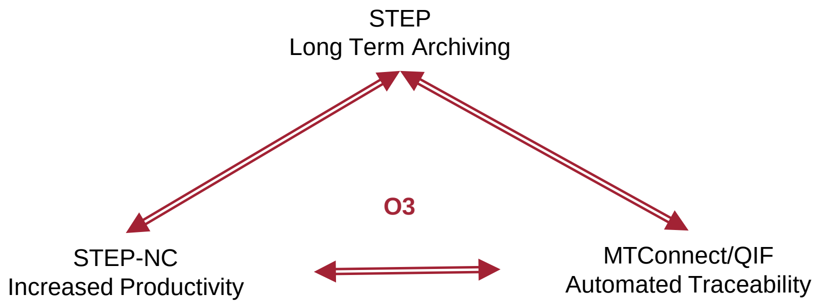


How?

- **Planning**
  - **UUID assigned to each tolerance and characteristic in STEP**
  - **UUID translated into CMM server database**
- **Manufacturing**
  - **UUID of measured characteristic put into MTConnect stream**
  - **UUID of measured characteristic put into QIF results**
  - **UUID of corresponding tolerance put into QIF results**
  - **UUID of tolerance read by digital twin**

Why? - Increased Productivity

- **Design requirements sent direct to planning and manufacturing**
  - **Automated planning to meet the tolerances**
  - **Automated detection and correction of anomalies**
- **Integration of CNC and CMM functions**
  - **Single setup**
  - **On demand measurement**
- **Tooling optimization**
  - **Feed speed optimization**
  - **Adaptive programming**



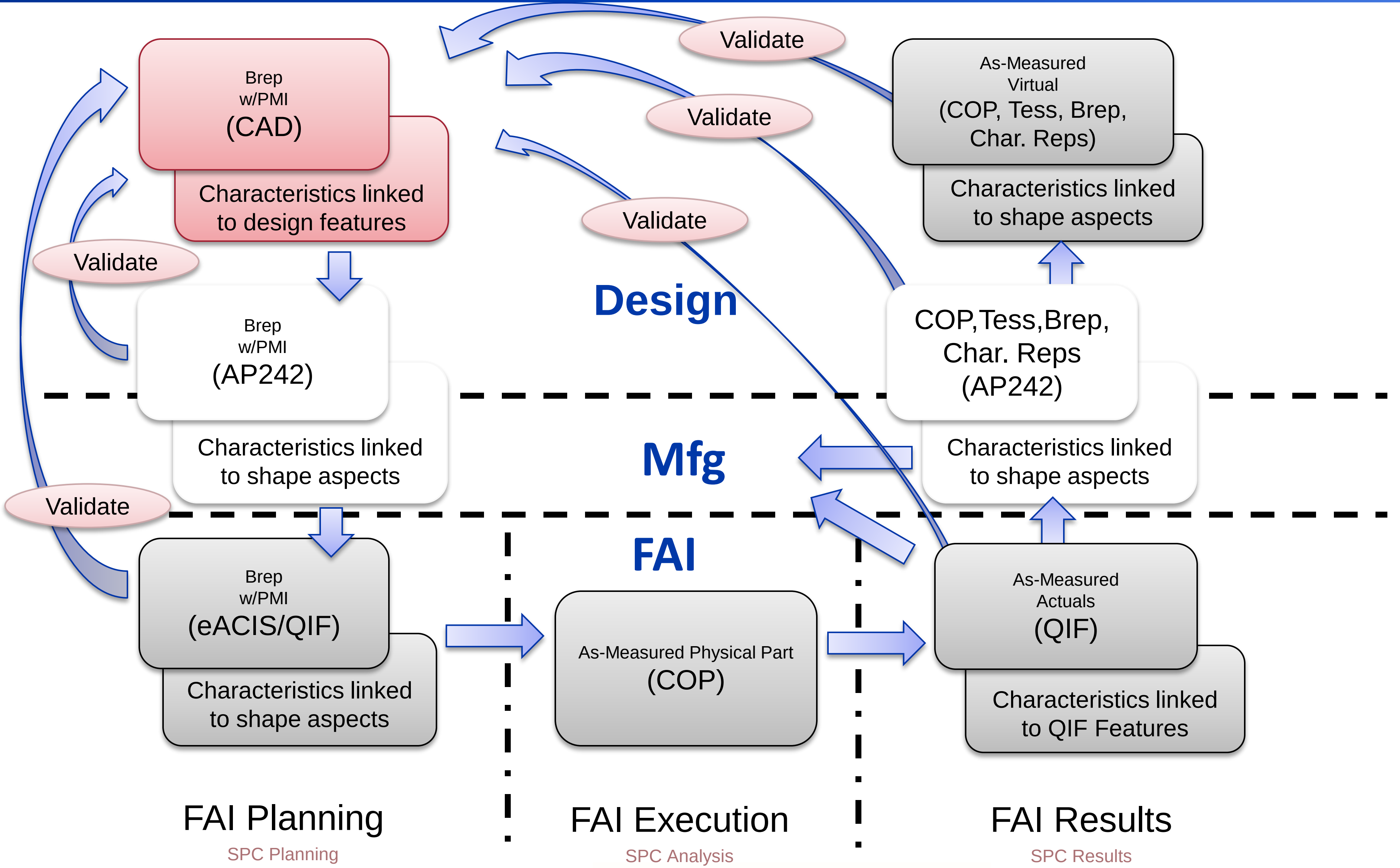
D2MIV 2 and DMDII O3

- **Near-term Gaps**
  - **Measurement Geometry – Taper Circle example (NIST FTC)**
  - **UOS Tolerance** *Demonstrated*
  - **Surface Roughness**
  - **Agreed upon list of assoc. features and characteristics**
  - **Criticality Attribute - safety or functional**
  - **Traceability - UUIDs/QPids** *Demonstrated*
  - **QIF Results back to Design and Manufacturing** *Demonstrated*
- **Longer-term Gaps**
  - **Authentication - security checksum**
  - **Extending Validation**
  - **Metadata – External to the model (who, what, where when and why)**
  - **Certification to Standards**

Design to Metrology - Vision

TBD

A Vision for Interop. between Design & Inspection



Next Steps

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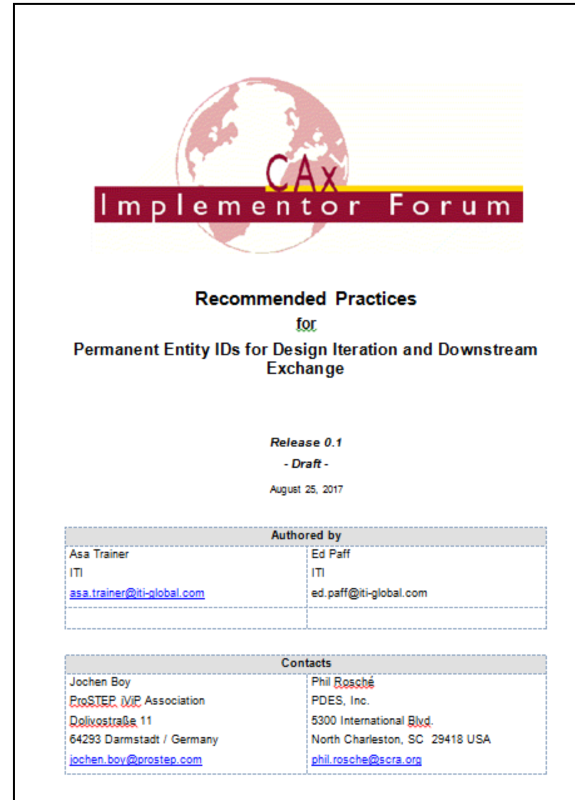
- **Gaps in PMI support important for Mfg/Metrology**
  - **Surface Finish, Welds, Material**
  - **Inclusion of Precision**
  - **UOS Tolerance**
- **UUIDs for Traceability**
  - **Recommended Practice for Cax Testing**
- **Demonstration of feedback from Metrology (QIF) to Design/Manufacturing (STEP)**
  - **Add Alternate Shape Representations**
  - **Add Alternate PMI elements**
  - **Add Status and RPN**


CAx Implementor Forum

Recommended Practices

for

Permanent Entity IDs for Design Iteration and Downstream Exchange

Release 0.1

- Draft -

August 25, 2017

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In closing…

- **The building blocks we are setting into place are now forming the foundation for a Standards-based MBE process**
  - **CAD companies, interop. vendors, end-users, and consortia are all engaged and benefiting from the results of early research**
  - **Engaging downstream vendors and consumers in the process will accelerate the momentum around MBE**
  - **Research is now beginning to deliver the promise of real benefits to downstream consumers of MBD data**

D2MI	D2MIV 1	DMDII O3	D2MIV 2
CAx-IF 3DPDF-IF	JT-IF	CAD & Interop. Vendors	End-user Companies
SFA	Conf/Val 1	Conf/Val 2	OSD TDGV Proto